BNL-1150

Subject Category: PHYSICS

UNITED STATES ATOMIC ENERGY COMMISSION

# SERIAL REPORTS ON START-UP EXPERIMENTS. NO. 2. THE UNIFORM TEMPERATURE COEFFICIENT OF THE BNL REACTOR

By
J. Chernick
J. W. Kunstadter



January 17, 1951

Brookhaven National Laboratory
Upton, New York

Technical Information Service, Oak Ridge, Tennessee

Work performed under Contract No. AT-30-2-Gen-16.

Date Declassified: November 14, 1955.



This report has been reproduced directly from the best available copy.

Issuance of this document does not constitute authority for declassification of classified material of the same or similar content and title by the same authors.

Printed in USA, Price 20 cents. Available from the Office of Technical Services, Department of Commerce, Washington 25, D. C.

GPO 822896 - 1

SERIAL REPORTS ON START-UP EXPERIMENTS

# #2. The Uniform Temperature Coefficient of the BNL Reactor

By J. Chernick and J. W. Kunstadter

January 17, 1951

## Introduction

On September 18, 1950, and again on September 24, experiments were conducted to obtain an overall temperature coefficient for the BNL reactor. The experiments consisted of drawing cool night air into the reactor and following the change in reactivity.

In the first attempt, two fans were turned on about half an hour before the reactor was brought to critical. As the reactor cooled, the increase in reactivity was measured by means of a calibrated control rod. The experimental procedure was the same as that used in the hot rod experiment and has been described in the first report of this series (BNL Log #C-4413).

The graphite, metal and air temperatures were recorded as a function of time by means of thermocouples placed in representative parts of the reactor. Temperature changes during a given interval of time were found to vary appreciably at different points in the reactor. Average values of the thermocouple readings were therefore used in obtaining the final values of the metal and graphite temperature coefficients.

In the second experiment which was run on September 24, the fans were not turned on until the reactor was critical. As a result, a larger change in reactor temperatures occurred during the early part of

this experiment. The latter part of the experiment was given over to the calibration of the #9 control rod.

Complete calibration curves for the #9 and #15 control rods were determined by combining the results from these experiments with those of other experiments conducted during the same period of time. The loading patterns were similar in all cases, since the evaluation of the Newson holes was being carried out at this time.

The change in the reactivity of the BNL reactor produced by the start-up or cut-off of the fans was readily observed during the present experiments. We give the results here, since they are of some interest in the control and operation of the reactor.

Results of the Experiment

The uniform temperature coefficient of the BNL reactor at a loading of 450-460 channels is found to be $-1.26 \pm 0.09$ inhours per $^{o}C$ rise in the overall reactor temperature. The coefficient can be separated into metal and graphite components on the basis of the present experiments, but with some loss of precision. The contribution of the metal coefficient turns out to be $-0.78 \pm 0.16$ ih/$^{o}C$ while that of the graphite coefficient is $-0.48 \pm 0.14$ ih/$^{o}C$. The better precision obtained for the overall coefficient is due to the fact that the values determined for the partial coefficients are interdependent. Although the determination of the partial coefficients is not as good as expected, the results show that the metal and graphite coefficients are of comparable magnitude. The importance of the metal coefficient, which has already been shown by the hot rod and reactor temperature flash experiments, is again verified.

The more important sources of error in the present experiments are the following:

1. Errors in control rod calibration.
2. Errors in barometric corrections due to fluctuations in fan speed and consequently in the pressure within the reactor.
3. Errors in thermocouple readings.
4. Errors in the values of the average metal and graphite temperature changes due to the fact that the latter vary significantly with position and hence may not be accurately represented by the few thermocouples in use.

In evaluating the data, a careful attempt has been made to reduce the control rod calibration error. The remaining loss of precision is believed to be due to (4) and possibly (2).

The change in reactivity caused by start-up or cut-off of the fans is estimated as 2 1/2 inhours at a measured air flow rate of 645,000 lb/hr and 3 1/2 inhours at an air flow rate of 680,000 lb/hr. These values have been corrected for simultaneous temperature changes.

<u>Experimental Details</u>

Loading patterns for the experiments were similar to those used in the Nowson hole runs (Fig. 5) viz., 461 channels with several central channels vacant. 453 channels were loaded in the September 18 run and 458 in the run made on September 24.

Thermocouples were located at the positions shown in the following table:

THERMOCOUPLE LOCATIONS

| Thermocouple | Type | Position in Reactor Coordinates |
|---|---|---|
| #1 | Metal | (7, 1, 5 1/4) |
| #2 | Metal | (3, 7, 5 1/4) |
| #3 | Metal | (2, 5, -5 1/4) |
| #4 | Air | (4, 7, -5 1/4) |
| #5 | Graphite | (-1/4, -10, -6 3/4) |
| #6 | Graphite | (1 3/4, 10, 6 3/4) |

Neutron counting rates were taken from three registers on a scale of 512 which were read consecutively at intervals of 20 seconds.

Barometric data were supplied by the Meteorology group. Barometer readings were also taken at the reactor site but these have been discarded as less accurate.

In the September 18 run (Fig. 1), the air flow rate was measured at 600,000 lb/hr at 15:23 and was raised to full current at 15:40. The measured flow rate at 21:00 was 645,000 ± 10,000 lb/hr. The neutron counters were turned on at 15:40 and the reactor started up at 15:45. The scram occurred at 23:55. The latter part of the run was used for control rod calibrations.

In the September 24 run the reactor was started up at 15:50. Three fans (#3, 4, 5) were cut in at 16:16. The measured air flow rate at 18:40 was 680,000 lb/hr. The run continued until 23:53 (Fig. 3).

## Control Rod Calibrations

Partial calibrations of the #9 and #15 control rods were obtained during several experiments conducted between September 18 and October 10, 1950. The loading patterns were basically that of the 461 channel pattern shown in Fig. 5 with a few unoccupied central channels.

The results of the October 10 calibrations are shown in Fig. 6. In Fig. 7, the sensitivity of the #9 rod at these loadings (452-460 channels) is compared with its sensitivity at a loading of 419 channels. The data obtained from all partial calibrations are here combined to obtain a complete curve of control rod sensitivity vs. rod postion. Theoretical sensitivity curves for various loadings are being prepared and will be given in a subsequent report. Preliminary results indicate that elementary control rod theory gives surprisingly good agreement with experiment.

Reduction of the Experimental Data

The data required to obtain the uniform temperature coefficients of the BNL reactor are shown in Tables I and II below. The times when the reactor was critical, and the corresponding rod positions and reactor temperatures may be read directly from the graphs. Plots of reactor temperatures vs time are given in Figs. 2 and 4.

TABLE I

Uniform Temperature Coefficient Experiment

Tabulation of Experimental Data: September 18, 1950

| Time at Critical | #9 Rod Position (cm) | Barometer (mm Hg) | Reactor Temperatures (°C) Recorded by Thermocouples #1 | #2 | #3 | #4 | #5 | #6 |
|---|---|---|---|---|---|---|---|---|
| 17:16 | 283.32 | 767.69 | 19.00 | 21.36 | 18.80 | 20.20 | 19.00 | 20.59 |
| 18:20 | 289.00 | 767.55 | 18.24 | 20.89 | 18.10 | 19.97 | 19.00 | 20.47 |
| 18:33 | 291.02 | 767.52 | 18.10 | 20.68 | 18.00 | 19.80 | 19.00 | 20.33 |
| 18:59 | 295.00 | 767.46 | 17.29 | 19.52 | 17.29 | 19.22 | 18.69 | 20.10 |
| 19:30 | 300.02 | 767.40 | 17.00 | 18.62 | 16.94 | 18.84 | 18.40 | 19.90 |
| 19:51 | 303.00 | 767.35 | 16.49 | 18.26 | 16.30 | 18.60 | 18.20 | 19.69 |
| 20:19 | 306.00 | 767.27 | 16.00 | 18.00 | 16.01 | 18.20 | 17.94 | 19.43 |
| 20:36 | 309.01 | 767.18 | 15.80 | 17.91 | 15.72 | 18.10 | 17.72 | 19.00 |
| 21:10 | 311.00 | 767.04 | 15.45 | 17.69 | 15.57 | 17.98 | 17.40 | 18.80 |
| 22:49 | 315.02 | 766.62 | 15.50 | 17.26 | 15.54 | 17.90 | 16.88 | 17.98 |

It is clear from inspection of Table I that the temperature drop recorded by the metal thermocouples (#1, 2 and 3) varies considerably with their position in the reactor. The total drop recorded by the #2 thermocouple is 4.1°C while the temperature change indicated by the #3 thermocouple is 3.3°C. The major drop in metal temperatures occurs during the first half of the experiment while the reverse is true of the graphite temperatures.

The data obtained from the September 24th run are shown in Table II.

TABLE II

Uniform Temperature Coefficient Experiment

Tabulation of Experimental Data: September 24, 1950

| Time at Critical | #9 Rod Position (cm) | Barometer (mm Hg) | Reactor Temperatures (°C) #1 | #2 | #3 | #4 | #5 | #6 |
|---|---|---|---|---|---|---|---|---|
| 16:48 | 565.00 | 758.22 | 14.77 | 14.78 | 16.43 | 17.70 | 19.51 | 20.32 |
| 16:59 | 570.00 | 758.26 | 14.23 | 14.04 | 15.96 | 17.37 | 18.85 | 19.89 |
| 17:19 | 575.00 | 758.35 | 13.46 | 13.60 | 15.40 | 16.86 | 18.00 | 19.12 |
| 17:37 | 580.00 | 758.43 | 13.05 | 13.20 | 14.88 | 16.40 | 17.48 | 18.50 |
| 18:01 | 585.00 | 758.58 | 12.32 | 12.30 | 14.38 | 15.73 | 16.50 | 17.69 |
| 18:49 | 590.00 | 759.12 | 11.60 | 11.60 | 13.71 | 14.97 | 15.13 | 16.46 |

In the determination of the uniform temperature coefficients, average values of the recorded metal and graphite temperatures were used. Changes in reactivity were computed from the differences in the #9 control rod settings at critical and were corrected for barometer. The results are shown in Table III.

## TABLE III

**1st run**

| Time Interval | Change in Average Metal Temperature | Change in Average Graphite Temperature | Inhours of Reactivity: Ih of Rod | Barometric Correction | Ih (Corr.) |
|---|---|---|---|---|---|
| 17:16 - 18:20 | .64 °C | .06 °C | .73 | -.06 | .67 |
| 18:20 - 18:33 | .15 | .07 | .27 | -.01 | .26 |
| 18:33 - 18:59 | .89 | .27 | .55 | -.02 | .53 |
| 18:59 - 19:30 | .51 | .24 | .72 | -.02 | .70 |
| 19:30 - 19:51 | .50 | .20 | .45 | -.02 | .43 |
| 19:51 - 20:19 | .35 | .26 | .46 | -.03 | .43 |
| 20:19 - 20:36 | .19 | .32 | .48 | -.04 | .44 |
| 20:36 - 21:10 | .24 | .26 | .32 | -.06 | .26 |
| 21:10 - 22:49 | .15 | .67 | .67 | -.17 | .50 |

**2nd run**

| Time Interval | Change in Average Metal Temperature | Change in Average Graphite Temperature | Inhours of Reactivity: Ih of Rod | Barometric Correction | Ih (Corr.) |
|---|---|---|---|---|---|
| 16:48 - 16:59 | .58 °C | .54 °C | .92 | .02 | .94 |
| 16:59 - 17:19 | .59 | .81 | .89 | .04 | .93 |
| 17:19 - 17:37 | .44 | .57 | .84 | .03 | .87 |
| 17:37 - 18:01 | .71 | .90 | .79 | .06 | .85 |
| 18:01 - 18:49 | .70 | 1.30 | .75 | .22 | .97 |

The metal and graphite temperature coefficients were found by least squares from the above data. The overall temperature coefficient obtained was $-1.26 \pm .09$ ih/°C. The contribution of the metal coefficient was $-0.78 \pm 0.16$ ih/°C, and that of the graphite coefficient $-0.48 \pm 0.14$ ih/°C. It may be noted that the precision of the overall temperature coefficient is much better than is indicated by the precision of the partial coefficients. The reason is that the latter coefficients are not determined independently. If we arbitrarily increase the graphite coefficient we get a corresponding decrease in the metal coefficient. Although the determination of the partial coefficients is not as good as expected, the results show that the metal and graphite coefficients are of comparable magnitude and the importance of the metal coefficient is again verified.

## The Effect of Fan Operation

The large changes in reactivity caused by the start-up or shutdown of the fans can be seen in Fig. 1 and 3. The barometric effect is almost instantaneous, and in the case of a fan start-up, is further enhanced by the sudden drop in metal temperatures. After correcting for the temperature effect we obtain the following data for the effect of fan operation.

Change in Reactivity Due to Fan Operation

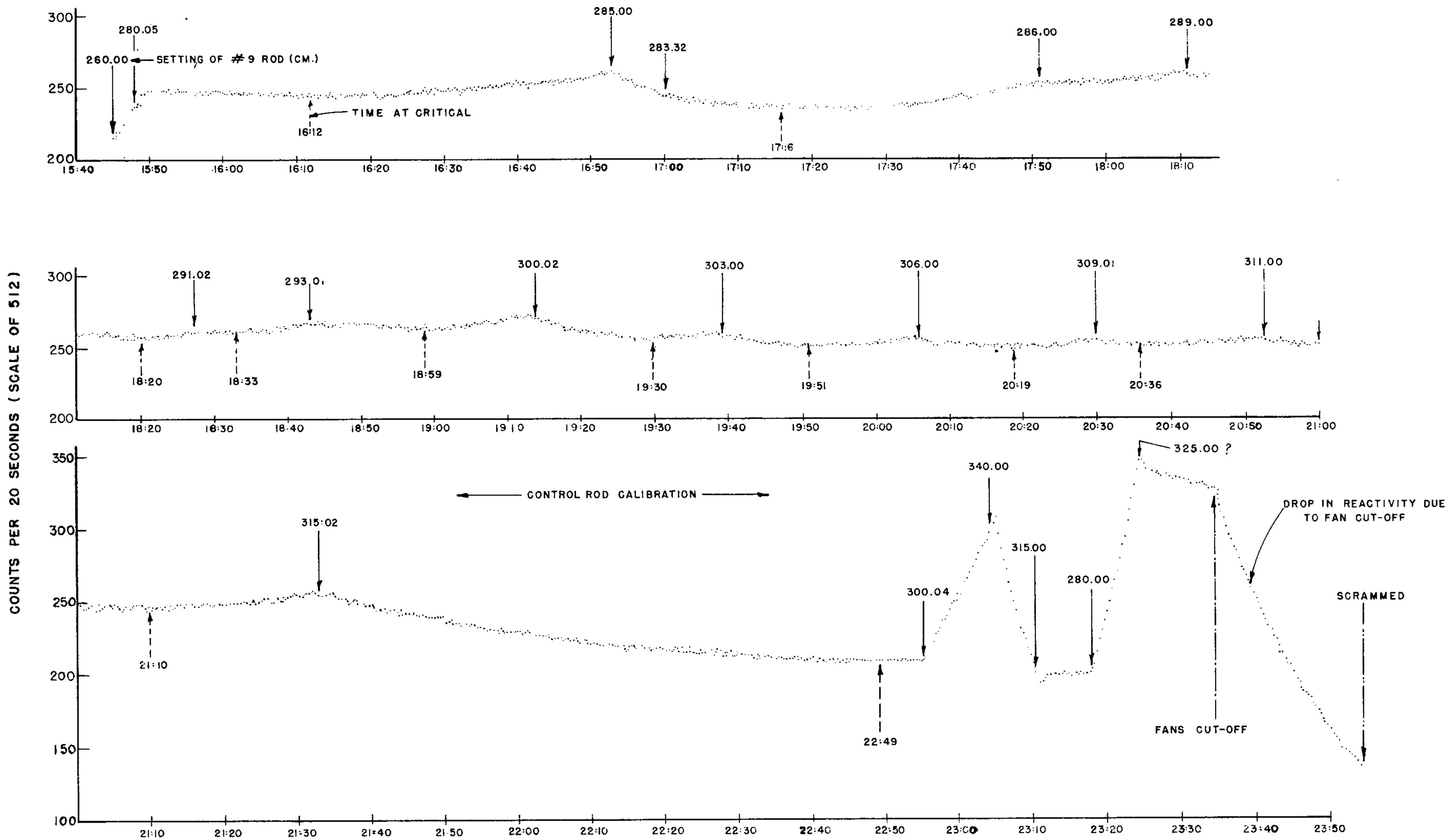
| Channels Loaded | Air Flow Rate (lb/hr) | Change in Reactivity (Ih) |
|---|---|---|
| 453 | 645,000 | 2 1/2 |
| 458 | 580,000 | 3 1/2 |

## FIG. 1

UNIFORM TEMPERATURE COEFFICIENT EXPERIMENT

( NEUTRON COUNTING RATE vs TIME )

SEPT. 18, 1950




BNL. LOG # D-1652

UNIFORM TEMPERATURE COEFFICIENT EXPERIMENT
REACTOR TEMPERATURE vs TIME
SEPT. 18, 1950

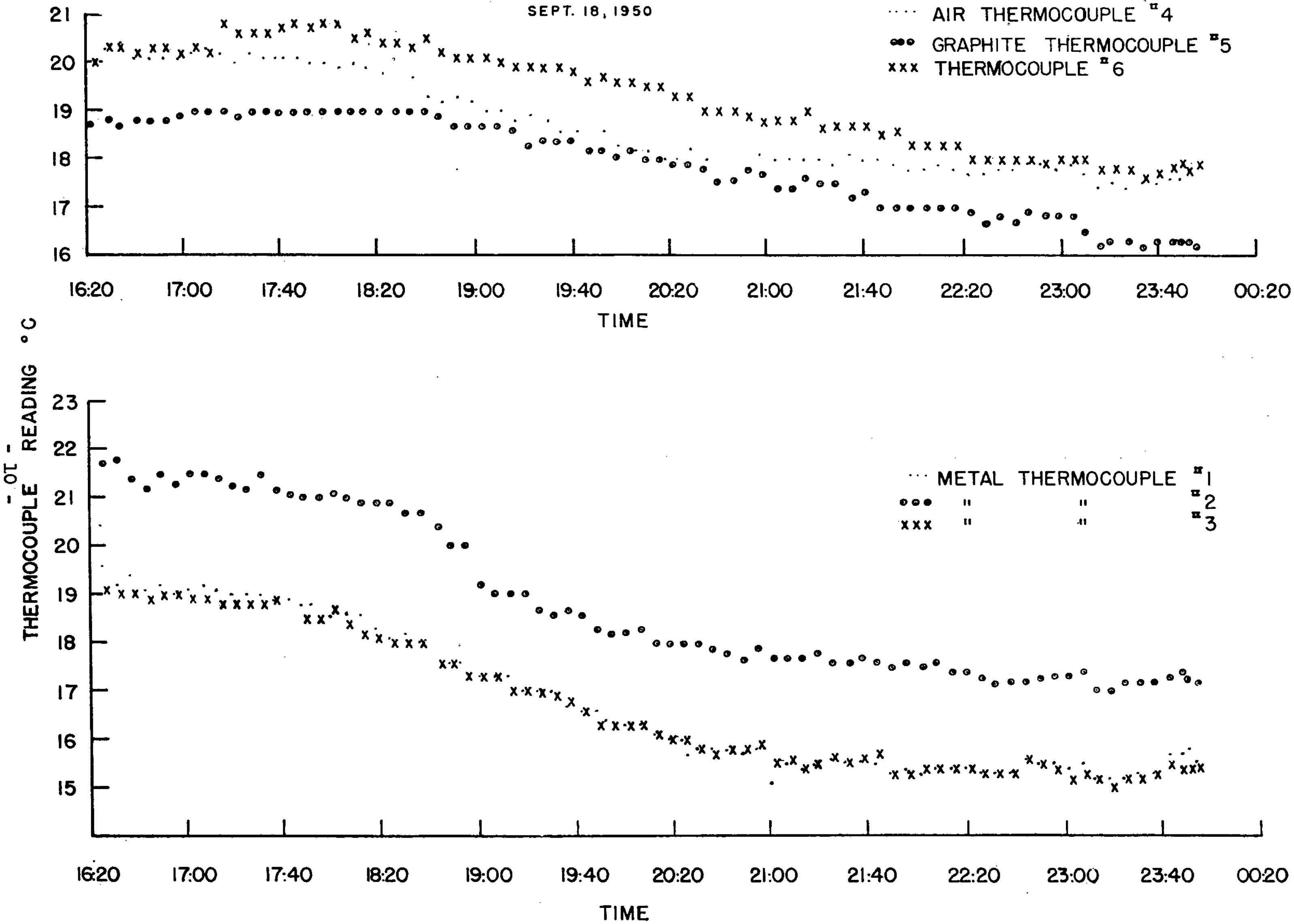
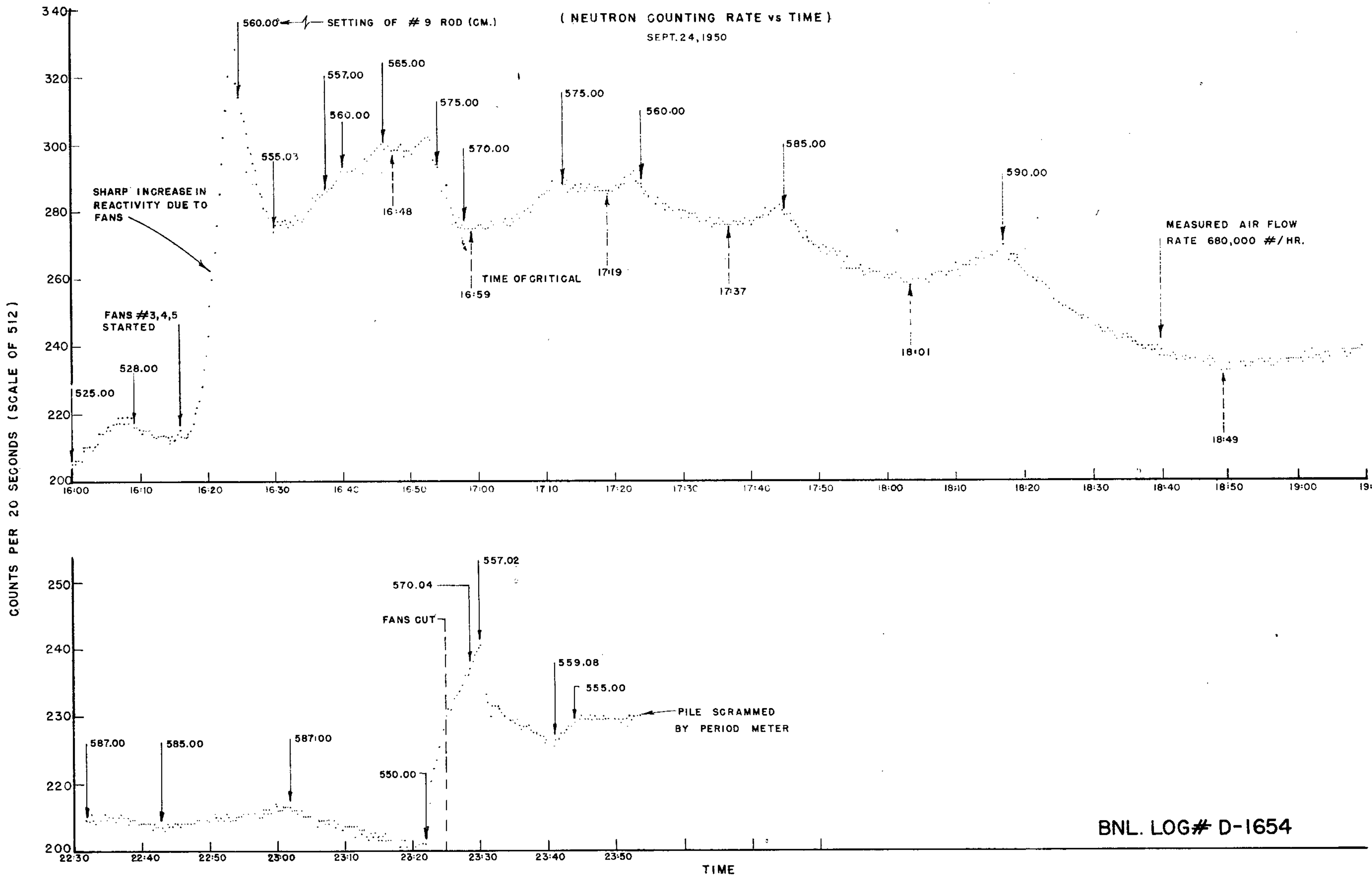



FIGURE 2

BNL.LOG. # D-1653

FIG. 3
UNIFORM TEMPERATURE COEFFICIENT EXPERIMENT
( NEUTRON COUNTING RATE vs TIME )
SEPT. 24, 1950




BNL. LOG# D-1654

UNIFORM TEMPERATURE COEFFICIENT EXPERIMENT
REACTOR TEMPERATURES vs TIME
SEPT. 24, 1950

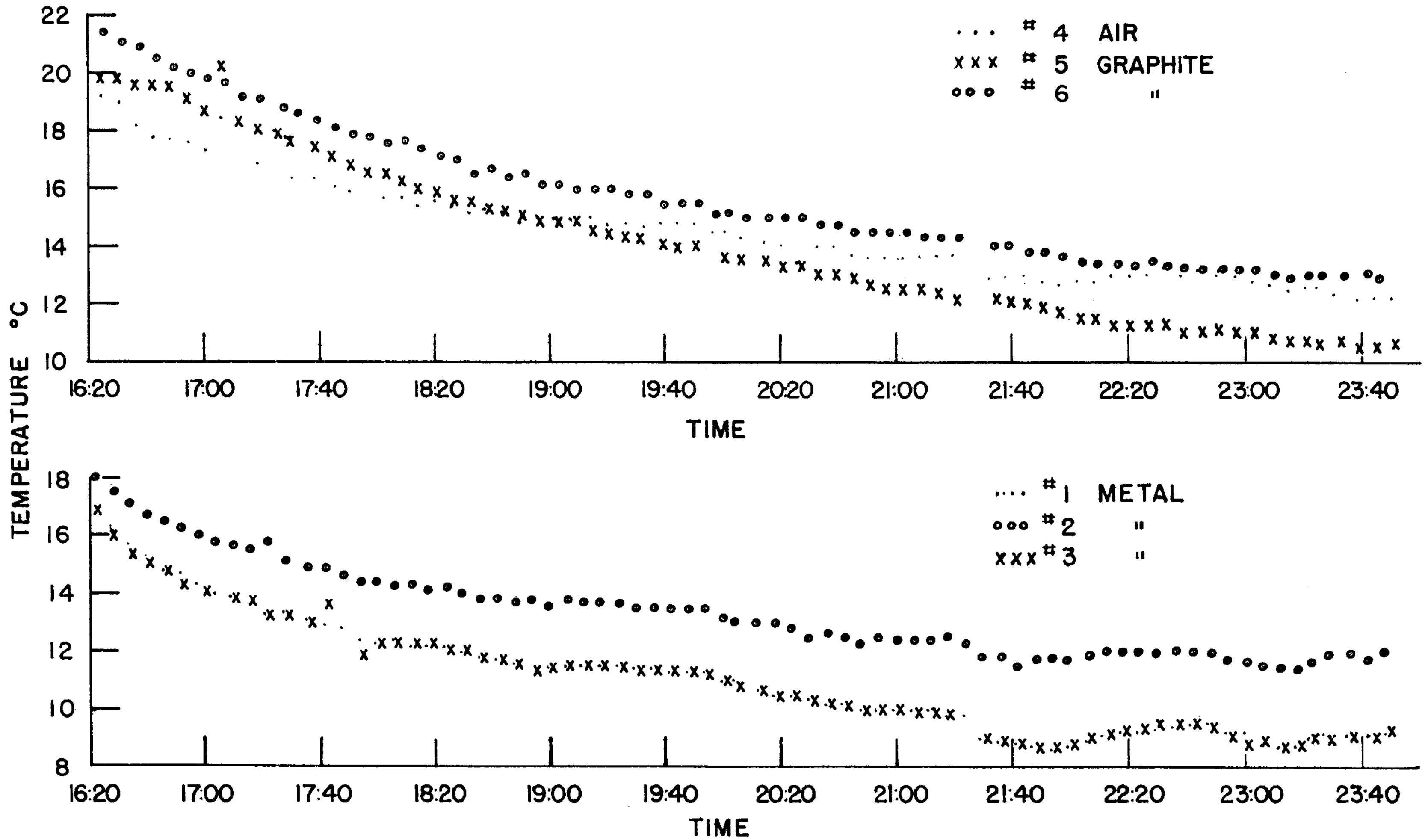
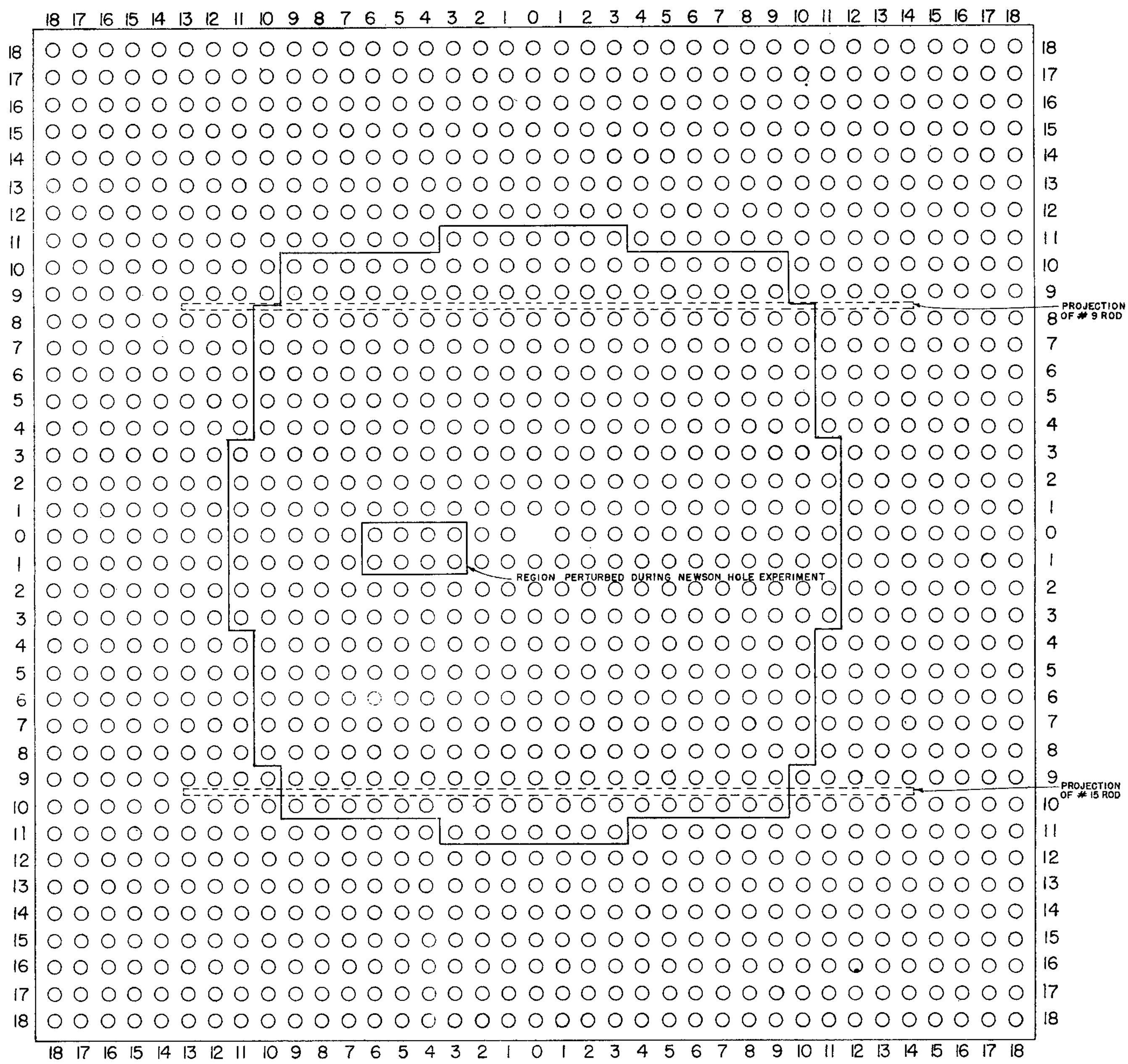



FIG. 4

BNL. LOG # D-1655




461 CHANNEL LOADING PATTERN

FIG. 5



BNL LOG # D-1646

CALIBRATION OF THE #9 AND #15 CONTROL RODS

LOADING: 460 CHANNELS (461 CHANNEL PATTERN, CENTRAL CHANNEL VACANT)

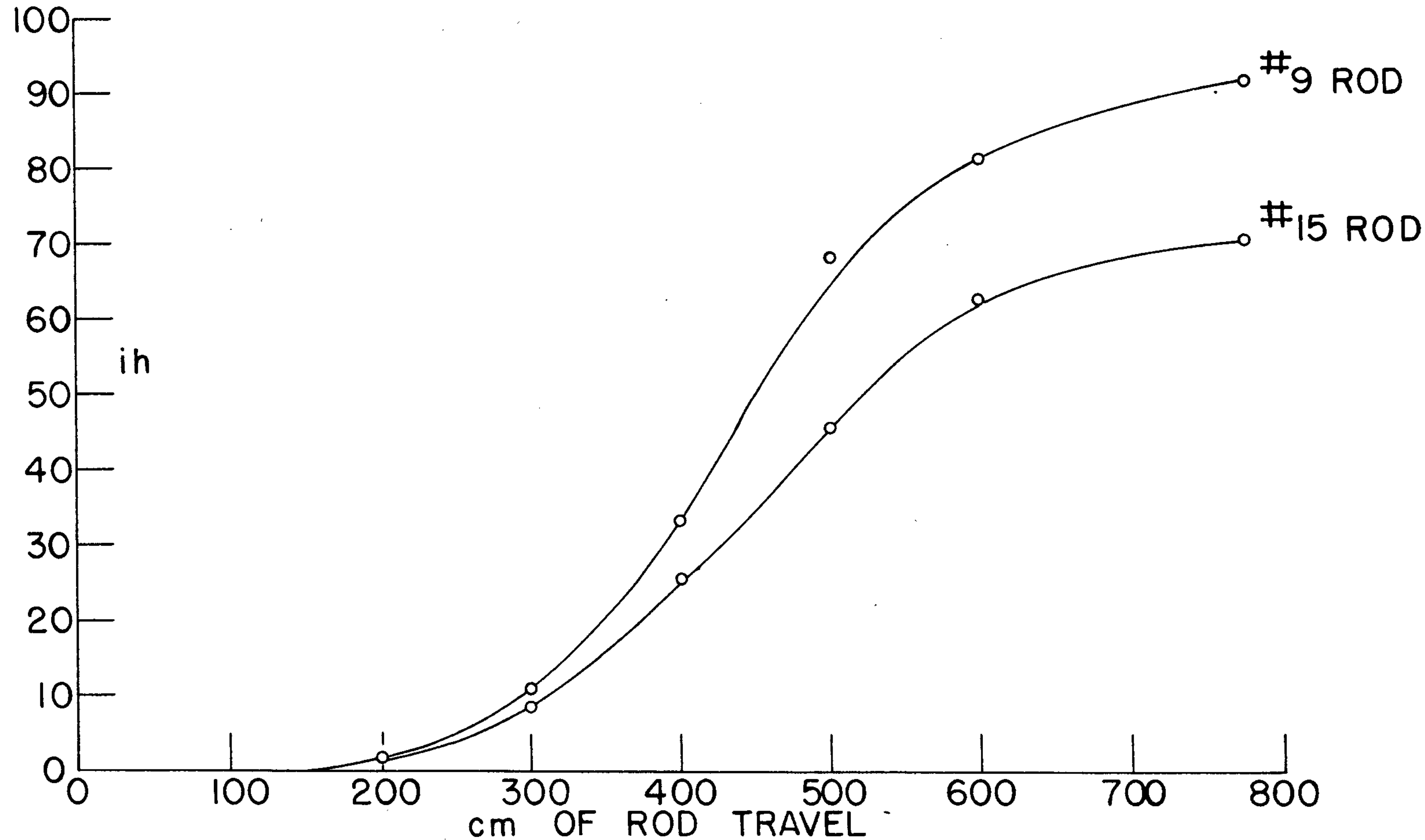



FIG. 6

BNL LOG # D-1656

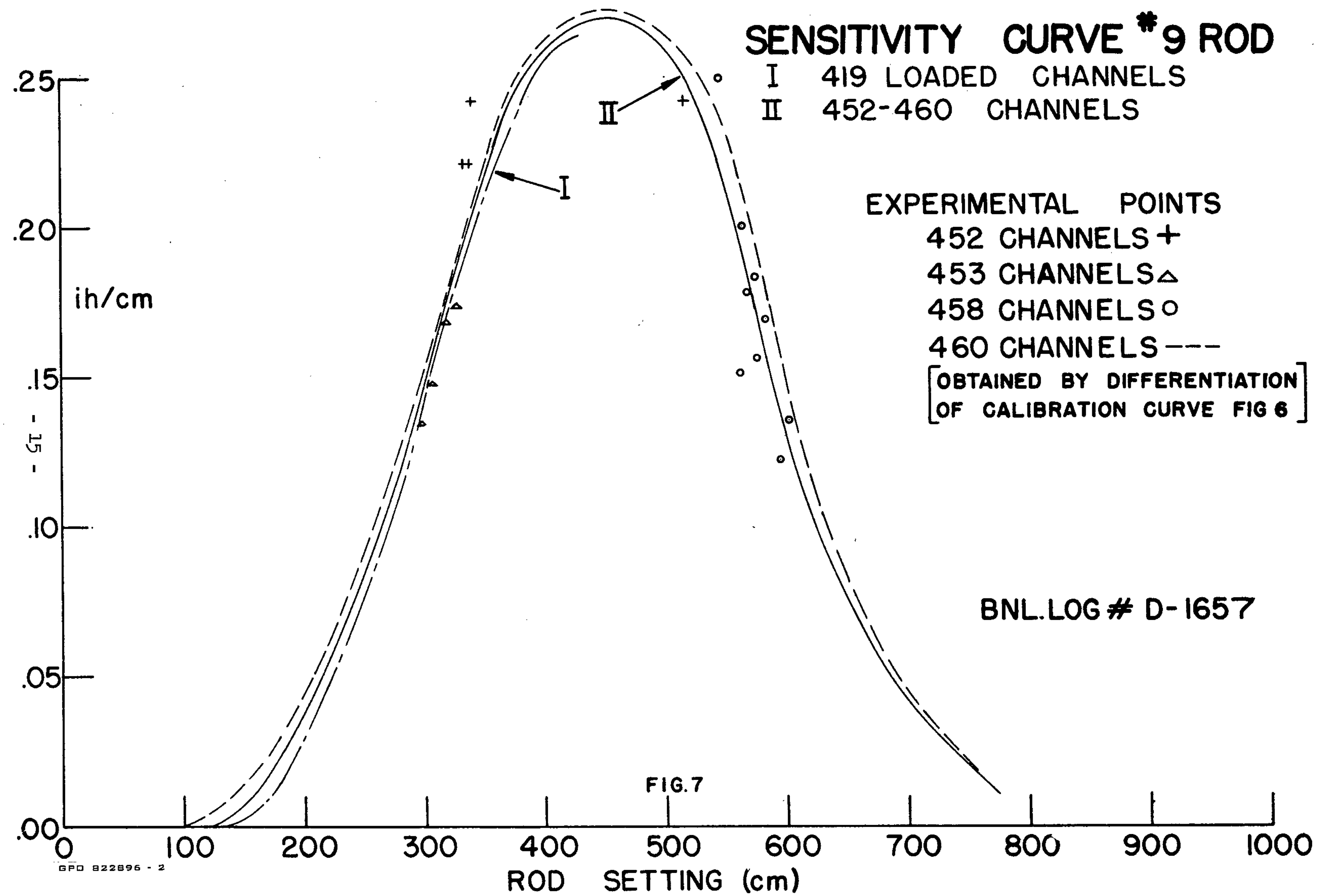

SENSITIVITY CURVE #9 ROD
I 419 LOADED CHANNELS
II 452-460 CHANNELS
EXPERIMENTAL POINTS
452 CHANNELS +
453 CHANNELS △
458 CHANNELS ○
460 CHANNELS ---
[OBTAINED BY DIFFERENTIATION OF CALIBRATION CURVE FIG 6]
BNL.LOG # D-1657
ih/cm
.25
.20
.15
.10
.05
.00
0
100
200
300
400
500
600
700
800
900
1000
ROD SETTING (cm)
I
II
GPO 822896 - 2

FIG.7